



Cyprinid fishes of the genus *Neolissochilus* in Peninsular Malaysia

M. Z. KHAIRONIZAM¹, M. ZAKARIA-ISMAIL & JONATHAN W. ARMBRUSTER²

¹*School of Biological Sciences, Universiti Sains Malaysia, 11800 Penang, Malaysia. E-mail: khaironizam@usm.my*

²*Department of Biological Sciences, 101 Life Sciences Building, Auburn University, Auburn, AL 36849, USA.*

E-mail: armbrjw@auburn.edu.

Email of Corresponding Author: khaironizam@usm.my

Abstract

Meristic, morphometric and distributional patterns of cyprinid fishes of the genus *Neolissochilus* found in Peninsular Malaysia are presented. Based on the current concept of *Neolissochilus*, only two species are present: *N. soroides* and *N. hendersoni*. *Neolissochilus hendersoni* differs from *N. soroides* by having lower scale and gill raker counts. *Neolissochilus soroides* has three mouth types (normal with a rounded snout, snout with a truncate edge, and lobe with a comparatively thick lower lip). A PCA of log-transformed measurements did not reveal significant differences between *N. hendersoni* and *N. soroides*, or between any of the morphotypes of *N. soroides*; however, a CVA of log-transformed measurements successfully classified 87.1% of all specimens. Removing body size by running a CVA on all of the principal components except PC1 (which was correlated with length) only slightly decreased the successful classification rate to 86.1%. Differences in morphometrics were as great between the three morphotypes of *N. soroides* as between any of the morphotypes and *N. hendersoni* suggesting that the morphotypes should be examined in greater detail with genetic tools. The PCA of morphometrics revealed separate clouds for *N. hendersoni* and *N. soroides*, but no differences between the *N. soroides* morphotypes. This study revealed that *N. hendersoni* is recorded for the first time in the mainland area of Peninsular Malaysia. Other nominal species of *Neolissochilus* reported to occur in the river systems of Peninsular Malaysia are discussed. *Lissochilus tweediei* Herre in Herre & Myers 1937 and *Tor soro* Bishop 1973 are synonyms of *Neolissochilus soroides*.

Key words: *Neolissochilus*, taxonomy, Peninsular Malaysia, Teleostei

Introduction

The cyprinid fishes of the genus *Neolissochilus* are widely distributed in freshwater habitats throughout tropical and subtropical areas of the southern and southeastern Asia (Rainboth 1991). Species of *Neolissochilus* have had a convoluted taxonomic history, and they have been placed under various genera, such as *Barbus* (M'Clelland 1839, 1845; Day 1869, 1870, 1871, 1873, 1878; Boulenger 1893; Duncker 1904, Pellegrin & Fang 1940), *Labeobarbus* (Weber & de Beaufort 1916), *Lissochilus* (Weber & de Beaufort 1916; Ahl 1933; Fowler 1934; Herre 1940), *Crossochilus* (Pellegrin & Chevey 1936; Herre & Myers 1937), *Puntius* (Smith 1945), and *Acrossocheilus* (Smith 1945).

Myers (1941) commented that the generic name *Lissochilus* described by Weber & de Beaufort (1916) is a junior homonym to the fossil gastropod genus *Lissochilus* (Pethö in Zittel 1881). Based on a single shared morphological character (a sharp, horny sheath covering of the lower jaw), Myers suggested placement of the fishes into *Acrossocheilus* (Oshima 1919). Rainboth (1985) reassessed this group of fishes and recognized the close relationship between them and *Tor* Gray as had also been suggested by several authors previously (Hora 1940, 1941; Hora & Misra 1941). Rainboth also commented that the sharp, horny sheath covering the lower jaw used to group fishes in *Acrossocheilus* is ecophenotypically variable as was found in other barbines, and therefore this character cannot serve as a primary distinguishing character. Based on several characters, such as the absence of the fleshy lobes on the lower lips, the development of a horny sheath on the lower jaw, low number of gill rakers on the lower arm, blunt, broad and longer snout, shallow and terete trunk, and shorter and more massive pharyngeal arch, Rainboth (1985) erected a new genus, *Neolissochilus*.

Due to the lack of morphological variation among the species, the taxonomy of this new genus has proven to be complex. Currently, there are 24 nominal species of *Neolissochilus* with sixteen of them described from Southeast Asian drainages (Rainboth 1985), including a recently described species from Thailand, *Neolissochilus subterraneus* Vidthayanon & Kottelat (2003).

In Peninsular Malaysia, *Neolissochilus* is locally known as 'ikan tengas' or 'copper mahseer' and is found in good quality, clear and rapid streams (Zakaria-Ismail & Fatimah 2002). The distribution of *Neolissochilus* in Peninsular Malaysia has been well documented (Duncker 1904; Weber & de Beaufort 1916; Herre & Myers 1937; Herre 1940; Ogilvie 1953; Menon 1954; Alfred 1963a, 1963b; Johnson 1967; Bishop 1973; Cramphorn 1983; Mohsin & Ambak 1983; Rainboth 1991; Zakaria-Ismail 1984, 1993; Zakaria-Ismail & Sabariah 1994; Zakaria-Ismail & Lim 1995; Doi 1997; Lim & Tan 2002; Zakaria-Ismail & Fatimah 2005; Ahmad & Lim 2006; Ambak & Jalal 2006; Esa *et al.* 2006). However, various names that have been used, and the number of species reported is variable. Doi (1997) reported six species, i.e. *Neolissochilus dukai*, *N. hendersoni*, *N. paucisquamatus*, *N. soroides*, *N. sumatranus* and *N. tweediei* in the Malay Peninsula but he did not specify which species occurred in Peninsular Malaysia. Ambak & Jalal (2006) and Esa *et al.* (2006) reported the occurrence of *N. hexagonolepis* and *N. stracheyi* in river systems of Peninsular Malaysia. Recently, Roberts & Khaironizam (2008) recognized polymorphism in *N. soroides* from Sungai Gombak of Selangor and described three morphotypes: 1) normal, which is rounded edge of lower jaw, 2) truncate, which is truncated edge with trenchant cutting edge, and 3) lobe, which is lower lip developed into mantel lobe.

The objective of this paper is to study the variation of fishes of the genus *Neolissochilus* in Peninsular Malaysia to determine which species are valid and whether or not the morphotypes of *N. soroides* can be differentiated morphometrically or meristically. The distributional pattern of *Neolissochilus* in Peninsular Malaysia is also provided.

Material and methods

The majority of the specimens used in this study were from the Zoological Museum of the Institute of Biological Sciences, Faculty of Sciences, University of Malaya (UMKL). Under material examined, the following data were given: institutional acronym and reference number, number of specimens examined, standard length or range of standard length, locality of the collection, date of collection and collector (s). For comparative purposes, some of the Malaysian and South Asian material from the California Academy of Sciences, formerly the Stanford University Collection (CAS-SU); National Museum of Natural History, Washington DC (USNM); and Zoological Reference Collection of the Raffles Museum of Biodiversity Research, National University of Singapore (ZRC), were examined. The abbreviation 'Sg.' is for 'Sungai' [= River] and 'SL' refers to standard length.

External morphology of each individual was observed and noted. Procedures for the 20 meristics and 36 morphometrics taken followed the standard procedures outlined by Hubbs & Lagler (1964) and Kottelat *et al.* (1993) or are self-explanatory. A total of 1459 specimens of *N. soroides* and 102 specimens of *N. hendersoni*, were examined from 75 localities of the 14 major drainages throughout Peninsular Malaysia (Fig. 1). Of those, 287 specimens had a full series of meristics and morphometrics (213 of *N. soroides* and 74 *N. hendersoni*), and the remainder were partially measured for their meristic and morphometric characters or identified based on their individual features. Other specimens labeled as *Barbus soroides* (1 specimen—Sg. Batang Padang in Perak, Peninsular Malaysia), *Lissochilus tweediei* (10 specimens—Sg. Yum in Perak, Peninsular Malaysia), *Lissochilus dukai* (1 specimen—Darjeeling, Himalayas, India), *Acrossocheilus hexagonolepis* (10 specimens—Chitawan Valley, Nepal) and *Lissochilus hendersoni* (10 specimens—Penang, Peninsular Malaysia) were used as comparative material.

The measurements were taken to the nearest 0.1 mm by using calipers and expressed as percentages of standard length (SL). Raw measurements were log-transformed in Excel and analyzed in JMP v. 11.0.0 (SAS Institute, 2013). A principal components analysis (PCA) and a canonical variates analysis (CVA) were performed on the log-transformed measurements. For the CVA, species and morphotype were used as the classification variable. The first three principal components and the three canonical variates were plotted against SL, and an ANOVA performed to determine whether or not they were correlated with overall size. Because CV1 was correlated with size, a second CVA for PC2-PC37 was performed. The resultant canonical variates were also tested

against SL. Meristics were examined in a separate PCA; 95% confidence intervals were calculated for each PC and CV plot.

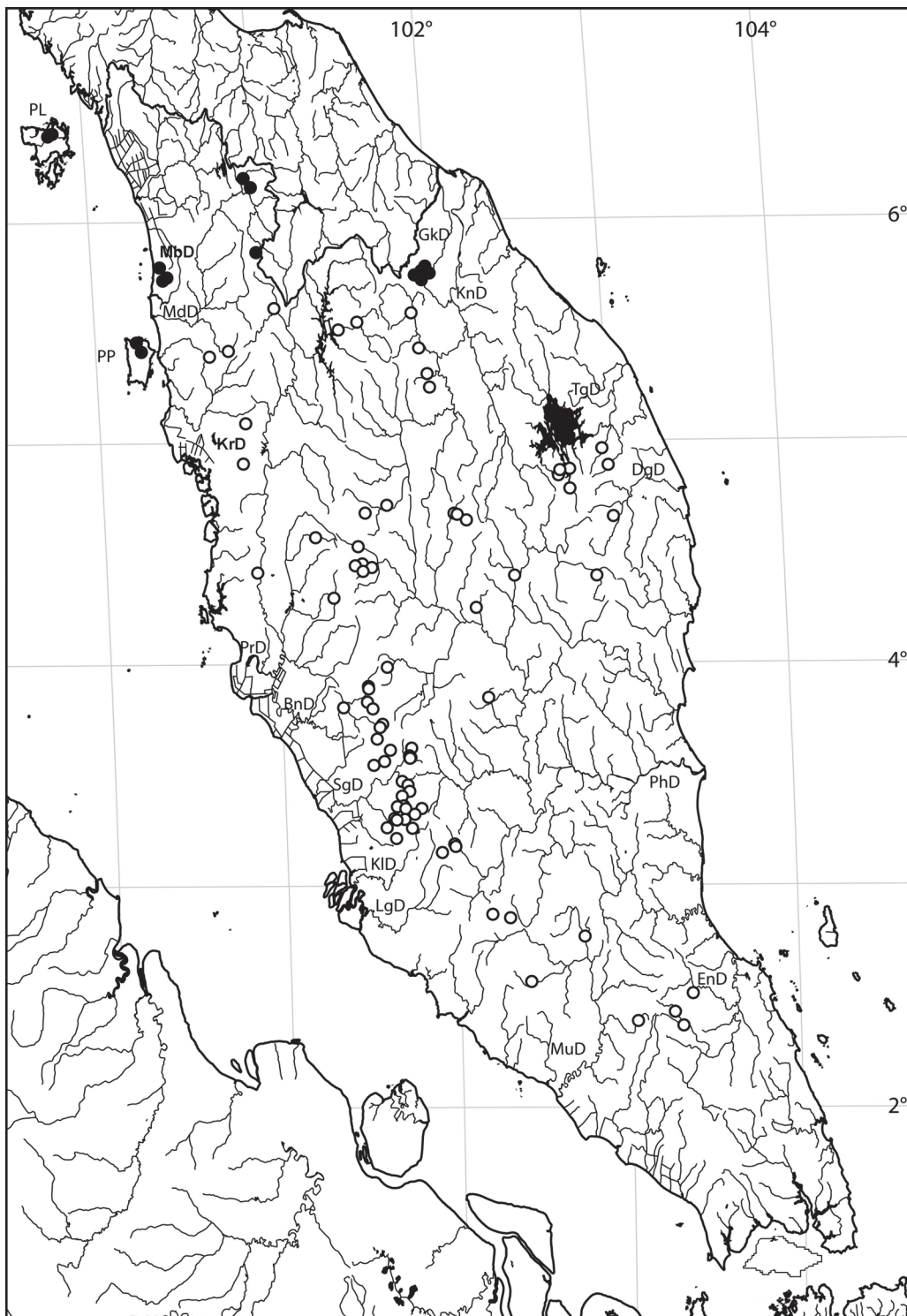


FIGURE 1. Geographic distribution of known localities of *Neolissochilus hendersoni* (dots) and *N. soroides* (circles) in Peninsular Malaysia. Drainages: BnD = Bernam, BsD = Besut, DgD = Dungun, EnD = Endau, GkD = Golok, KID = Klang, KnD = Kelantan, KrD = Kurau, LgD = Langat, MbD = Merbok drainage, MdD = Muda, MuD = Muar, PhD = Pahang, PL = Pulau Langkawi, PrD = Perak, PP = Pulau Pinang, SgD = Selangor and TgD = Terengganu.

In addition, morphometrics were plotted against SL to determine if there appeared to be any biologically significant differences between species or morphotypes. Two characters, Lower Jaw Length and Lower Jaw Width

appeared to show significant differences between morphotypes of *N. soroides*, and were plotted against one another. An ANCOVA was performed in JMP using the “Fit Model” command and Standard Least Squares. Log-transformed Lower Jaw Length was chosen as the variable and log-transformed Lower Jaw Width and Species/Morphotype chosen as the Model Effects. A Tukey HSD posthoc test was employed to evaluate pairwise differences between species.

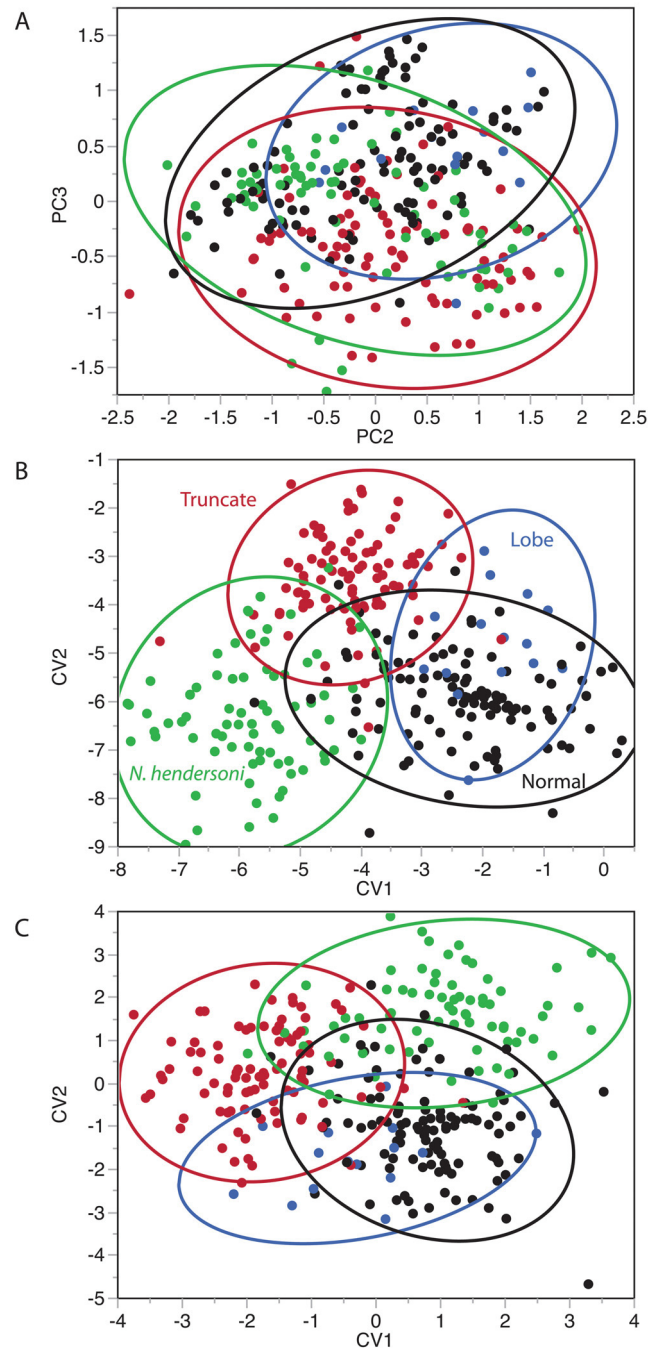


FIGURE 2. Results of morphometric analyses. A) PCA: PC2 was most strongly influenced positively by Upper Lips Thickness, Lower Jaw Width, and Snout Length, and negatively by Body Depth, Anal-fin Base Length, and Dorsal-fin Base Length; PC3 was most strongly influenced positively by Lower Jaw Length, Head Width, and Orbital Length, and negatively by Upper Lips Thickness, Depressed Dorsal-fin Length, and Dorsal-fin Base Length. B) CVA of all log-transformed morphometric data: CV1 was most strongly influenced positively by Post-pectoral-fin Length, Head Length, and Dorsal-fin Height, and negatively by Standard Length, Pre-anal Length, and Body Depth; CV2 was most strongly influenced positively by Post-dorsal-fin Length, Pre-dorsal Length, and Pre-nostril Length. C) CVA on principal components, excluding PC1.

TABLE 1. Meristic and morphometric features of three mouth types of *N. soroides* in Peninsular Malaysia.

Characters	Normal mouth type (n=108, 38.2-153.2 mm SL)	Truncate mouth type (n=90, 40.6-144.4 mm SL)	Lobe mouth type (n=15, 63.3-120.0 mm SL)
Meristic			
Dorsal-fin spines and rays	iv, 9	iv, 9	iv, 9
Anal-fin spines and rays	iii, 5	iii, 5	iii, 5
Pectoral-fin spines and rays	i, 14-15 (14.5±0.5)	i, 14-15 (14.5±0.5)	i, 14-15 (14.3±0.5)
Pelvic-fin spines and rays	i, 8	i, 7-8 (8.0±0.1)	i, 8
Lateral-line scales	20-24 (22.4±0.8)	21-24 (22.3±0.6)	21-23 (22.1±0.6)
Scales in lateral line on hypural plates	2-3 (2.8±0.4)	2-3 (2.8±0.4)	3
Scales above lateral line	3-5	3-5	3-5
Scales below lateral line	2.5-3.5 (2.7±0.4)	2.5-3.5 (2.8±0.4)	2.5-3.5 (2.8±0.4)
Circumferential scale rows	16-18 (17.0±0.9)	16-18 (16.9±0.9)	16-18 (17.5±0.9)
Circumpeduncular scale rows	12	12	12
Predorsal scales	8-10 (8.4±0.5)	8-10 (8.5±0.6)	8-10 (8.4±0.6)
Scales at dorsal-fin base	7-10 (8.4±0.7)	7-9 (8.3±0.5)	8-9 (8.4±0.5)
Scales from end of dorsal-fin base to origin of caudal-fin base	12-15 (13.5±0.8)	12-15 (13.4±0.5)	12-14 (13.0±0.7)
Scales from isthmus to pelvic-fin base	12-14 (13.3±0.5)	12-14 (13.2±0.4)	13-14 (13.2±0.4)
Scales from end of pelvic-fin base to origin of anal-fin base	5-6 (5.6±0.5)	5-6 (5.7±0.5)	5-6 (5.8±0.4)
Scales at anal-fin base	4-6 (4.9±0.4)	4-6 (4.8±0.5)	5
Scales from end of anal-fin base to origin of caudal-fin base	6-8 (6.7±0.5)	6-8 (6.6±0.5)	6-7 (6.9±0.4)
Total gill rakers	14-17 (16.0±0.8)	15-17 (16.3±0.7)	15-17 (16.2±0.9)
Gill rakers on lower arm	10-12 (10.7±0.7)	10-12 (10.7±0.6)	10-12 (10.9±0.7)
Gill rakers on upper arm	4-5 (4.4±0.5)	4-5 (4.5±0.5)	4-5 (4.3±0.5)
Morphometric (in % SL)			
Body depth	26.2-35.5 (30.4±1.7)	26.2-35.9 (31.0±2.2)	26.8-33.4 (30.1±1.9)
Head length	26.8-32.2 (29.4±1.2)	26.9-33.1 (29.3±1.5)	27.9-31.6 (29.5±1.1)
Head depth	17.8-25.5 (22.6±1.2)	19.8-24.6 (22.7±1.0)	20.9-24.3 (23.1±0.9)
Head width	14.9-24.0 (18.4±1.9)	14.4-23.0 (18.3±1.8)	17.3-21.2 (18.8±1.1)

...Continue on next page

TABLE 1 (continued). Comparative meristic and morphometric features between three mouth types of *N. soroides* from Peninsular Malaysia.

Characters	Normal mouth type (n=108, 38.2-153.2 mm SL)	Truncate mouth type (n=90, 40.6-144.4 mm SL)	Lobe mouth type (n=15, 63.3-120.0 mm SL)
Snout length	6.6-12.1 (10.3±0.9)	8.6-12.7 (10.5±1.0)	9.8-11.6 (10.7±0.5)
Pre-nostril length	7.2-9.7 (8.5±0.6)	7.0-10.9 (8.9±0.9)	7.8-9.7 (8.9±0.5)
Eye diameter/length	5.0-8.7 (6.8±0.6)	5.3-8.7 (6.9±0.7)	5.8-8.4 (6.8±0.7)
Pre-occipital length	20.2-26.3 (23.0±1.2)	18.9-28.1 (23.4±1.6)	21.3-24.6 (23.1±0.9)
Pre-operculum length	18.3-24.0 (21.2±1.1)	17.6-25.1 (21.3±1.5)	20.2-21.7 (20.9±0.5)
Caudal-peduncle length	13.9-18.9 (16.5±1.0)	12.8-19.1 (16.3±1.2)	15.7-18.7 (17.2±0.7)
Caudal-peduncle depth	10.8-13.6 (12.0±0.6)	10.3-13.8 (12.1±0.7)	10.8-13.1 (11.8±0.7)
Dorsal-fin base length	14.6-19.8 (16.6±1.0)	15.3-18.9 (16.8±0.9)	14.7-17.8 (16.1±1.0)
Dorsal-fin depressed length	25.6-33.4 (29.1±1.6)	25.6-33.7 (29.9±1.6)	26.4-31.8 (29.3±1.6)
Dorsal-fin height	19.7-27.4 (23.4±1.4)	20.3-28.3 (23.6±1.5)	21.0-25.6 (23.7±1.50)
Anal-fin base length	6.5-9.0 (7.9±0.5)	6.4-9.3 (7.8±0.5)	7.0-8.4 (7.6±0.4)
Anal-fin depressed length	18.0-25.0 (20.8±1.3)	18.0-24.7 (21.1±1.3)	19.8-23.2 (21.7±1.0)
Anal-fin height	15.7-23.2 (18.8±1.5)	15.2-22.7 (19.2±1.2)	17.6-20.6 (19.4±0.9)
Pectoral-fin length	19.9-26.7 (23.7±1.4)	21.2-27.6 (24.4±1.4)	22.8-26.4 (24.8±1.1)
Pelvic-fin length	17.8-23.8 (21.1±0.8)	18.2-23.9 (21.0±1.3)	18.9-22.6 (21.0±1.2)
Pre-dorsal length	47.5-55.5 (51.6±1.2)	48.2-57.0 (51.8±1.8)	49.7-54.4 (51.9±1.4)
Post-dorsal length	51.1-60.4 (54.4±2.1)	51.1-59.7 (55.1±2.2)	51.1-55.6 (53.2±1.5)
Pre-pectoral length	25.6-33.2 (29.2±1.8)	23.8-33.1 (29.2±1.8)	26.4-32.3 (29.3±1.6)
Post-pectoral length	62.3-79.9 (74.5±2.3)	69.5-79.8 (74.5±2.4)	69.8-76.1 (73.9±2.0)
Pre-anal length	75.9-82.1 (78.3±1.6)	74.1-84.3 (78.7±1.9)	74.9-82.3 (77.6±1.8)
Post-anal length	21.3-27.4 (24.3±1.3)	19.8-27.1 (23.9±1.4)	23.4-26.2 (24.3±0.9)
Pre-pelvic length	50.7-57.9 (54.3±1.7)	49.3-59.7 (54.5±2.1)	51.3-56.0 (53.7±1.3)
Post-pelvic length	46.0-55.9 (50.0±1.7)	45.6-54.2 (49.5±1.9)	47.6-51.8 (49.7±1.4)
Length from dorsal-fin base to pectoral-fin base	21.4-39.1 (33.0±2.3)	20.7-39.4 (33.0±2.5)	29.5-35.4 (32.9±2.1)
Length from dorsal-fin base to anal-fin base	33.7-43.1 (39.2±1.7)	36.2-43.1 (39.5±1.6)	35.6-40.3 (38.1±1.5)
Length from pelvic-fin base to anal-fin base	23.2-29.1 (25.8±1.2)	23.1-29.5 (25.7±1.2)	22.9-27.2 (25.0±1.3)
Length from pectoral-fin base to pelvic-fin base	23.1-30.4 (26.5±1.3)	22.3-29.7 (26.7±1.3)	23.7-28.5 (26.0±1.3)
Length from pectoral-fin base to anal-fin base	47.4-56.9 (51.5±1.8)	47.0-55.5 (51.3±1.7)	46.3-53.8 (50.2±1.9)
Lower jaw length	5.6-11.5 (8.6±1.3)	4.5-11.1 (6.8±1.3)	5.7-15.7 (9.4±2.2)
Lower jaw width	6.0-11.5 (8.2±1.2)	6.0-12.3 (9.1±1.1)	6.8-11.0 (8.7±1.1)
Upper lip thickness	1.5-2.2 (1.8±0.2)	1.0-2.4 (1.8±0.3)	1.6-2.1 (1.8±0.2)
Lower lip thickness	1.1-2.5 (1.8±0.3)	1.2-2.4 (1.7±0.3)	1.4-2.4 (2.0±0.3)

Results

Observations on 213 specimens of *Neolissochilus soroides* revealed 108 with the normal mouth type, 90 specimens with the truncate mouth type, and 15 with the lobe mouth type. Table 1 shows the meristic and morphometric data on the three morphotypes. Comparative meristic and morphometric characters of *N. hendersoni* and *N. soroides* are in Table 2. PCA of measurements (Fig. 2A) failed to demonstrate any major differences between species or between morphotypes, but there is a slight trend towards lower PC3 scores in the truncate morphotype compared to those in the normal and lobe morphotypes. PC1 was found to be significantly correlated with size, but PC2 and PC3 were not (Table 3A). PCA on meristics (Fig. 3) yielded significant differences between *Neolissochilus hendersoni* and *N. soroides*, but there were no differences between the morphotypes of *N. soroides*.

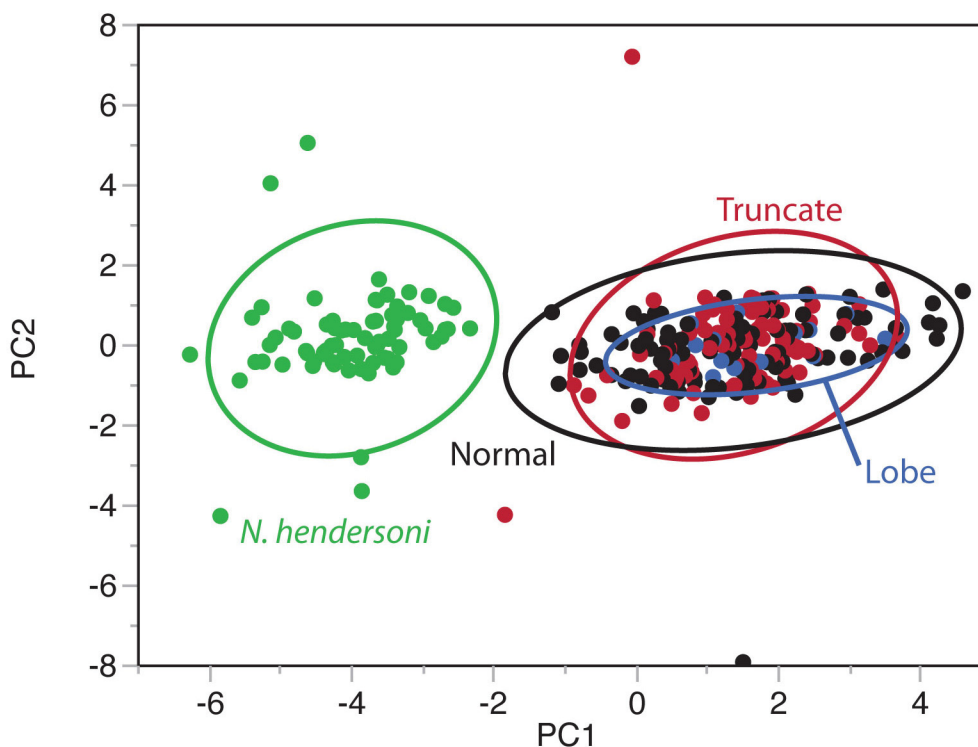


FIGURE 3. Principal Components Analysis of meristic data. *Neolissochilus hendersoni* and *N. soroides* separated only along PC1, which was most strongly influenced positively by Total Gill Rakers, Scales from Isthmus to Pelvic-fin base, and Gill Rakers on Lower Arm, and negatively by Scales at Anal-fin Base.

CVA on log-transformed data was remarkably successful in correctly predicting group identity (87.1% of specimens correctly classified to species or morphotype; Fig. 2B: Table 4A); however, CV1 was significantly correlated with size (Table 3B), and was one of the most strongly loaded variables on CVA. Given that the size range of each species/morphotype was roughly equivalent, this is not likely to be a major factor; however, a second CVA on the PC scores excluding PC1 (Fig. 2C) was similar to the original CVA with just a slight reduction in percent of specimens correctly classified to species or morphotype (86.1% of specimens correctly classified to species or morphotype; Table 4B). None of the CV's on PC scores were correlated with size (Table 3C).

Analysis of Lower Jaw Length vs. Lower Jaw Width (Fig. 4) showed differences between at least the normal plus lobe morphotypes and the truncate morphotype. ANCOVA revealed significant differences between the truncate and the normal and lobe morphotypes ($p < 0.0001$), and each of the *N. soroides* morphotypes was significantly different from *N. hendersoni* (vs. normal $p < 0.001$, vs. truncate $p = 0.0009$, vs. lobe $p = 0.0012$). Only the normal and lobe morphotypes were not significantly different ($p = 0.992$) from one another.

Discussion

Meristic and morphometric data on *Neolissochilus* revealed that only two species occur in the river systems of Peninsular Malaysia: *N. hendersoni* and *N. soroides*. Although both species have similar morphology and numbers of fin rays, the numbers of scales and gill rakers are smaller in *N. hendersoni*. Although there is some overlap in meristics, the PCA of meristics showed complete separation between *N. hendersoni* and *N. soroides*.

TABLE 2. Comparison of meristic and morphometric features of *N. hendersoni* and *N. soroides* from Peninsular Malaysia.

Characters	<i>N. hendersoni</i> (n=74, 44.6-122.7 mm SL)	<i>N. soroides</i> (n=213, 38.2-153.2 mm SL)
Meristics		
Dorsal-fin spines and rays	iv, 9	iv, 9
Anal-fin spines and rays	iii, 5	iii, 5
Pectoral-fin spines and rays	i, 14-15 (14.3±0.5)	i, 14-15 (14.5±0.5)
Pelvic-fin spines and rays	i, 7-8 (8.0±0.2)	i, 7-8 (8.0±0.1)
Lateral-line scales	18-22 (20.0±0.8)	20-24 (22.3±0.7)
Scales in lateral line on hypural plates	2-3 (2.0±0.2)	2-3 (2.8±0.4)
Scales above lateral line	3.5	3.5
Scales below lateral line	2.0-3.0 (2.0±0.2)	2.5-3.5 (2.8±0.4)
Circumferential scale rows	16-18 (16.4±0.7)	16-18 (17.0±0.9)
Circumpeduncular scale rows	12	12
Pre-dorsal scales	6-8 (7.7±0.5)	8-10 (8.5±0.6)
Scales at dorsal-fin base	7-9 (8.1±0.6)	7-10 (8.3±0.6)
Scales from end of dorsal-fin base to origin of caudal fin	10-13 (12.2±0.8)	12-15 (13.4±0.7)
Scales from isthmus to pelvic-fin base	10-12 (10.7±0.8)	12-14 (13.2±0.5)
Scales from end of pelvic-fin base to origin of anal-fin base	4-6 (5.3±0.5)	5-6 (5.6±0.5)
Scales at anal fin base	3-5 (4.1±0.3)	4-6 (4.9±0.4)
Scales from end of anal-fin base to origin of caudal fin	5-6 (5.9±0.3)	6-8 (6.6±0.5)
Total gill rakers	12-14 (13.8±0.5)	14-17 (16.1±0.8)
Gill rakers on the lower arms	9-10 (9.3±0.5)	10-12 (10.7±0.8)
Gill rakers on the upper arms	3-4 (3.5±0.5)	4-5 (4.5±0.5)
Morphometric (in % SL)		
Body depth	27.6-35.6 (31.1±1.6)	26.2-35.9 (30.7±2.0)
Head length	26.4-31.3 (28.9±1.2)	26.8-33.1 (29.4±1.3)
Head depth	19.8-25.5 (23.0±1.2)	17.8-25.5 (22.7±1.1)
Head width	15.4-19.6 (17.7±1.0)	14.4-24.0 (18.4±1.8)
Snout length	8.6-11.6 (10.2±0.7)	6.6-12.7 (10.4±0.9)
Pre-nostril length	7.0-9.6 (8.3±0.6)	7.0-10.9 (8.7±0.7)
Eye diameter/length	5.9-8.7 (7.3±0.6)	5.0-8.7 (6.8±0.7)

TABLE 2 (continued). Comparison of meristic and morphometric features of *N. hendersoni* and *N. soroides* from Peninsular Malaysia.

Characters	<i>N. hendersoni</i>	<i>N. soroides</i>
	(n=74, 44.6-122.7 mm SL)	(n=213, 38.2-153.2 mm SL)
Pre occipital length	20.9-26.0 (23.4±1.1)	18.9-28.1 (23.2±1.4)
Pre operculum length	19.2-22.9 (21.1±0.9)	17.6-25.1 (21.2±1.2)
Caudal-peduncle length	13.8-19.4 (16.4±1.1)	12.8-19.1 (16.5±1.1)
Caudal-peduncle depth	10.9-13.8 (12.5±0.6)	10.3-13.8 (12.0±0.6)
Dorsal-fin base length	14.8-19.1 (16.9±0.9)	14.6-19.8 (16.6±1.0)
Dorsal-fin depressed length	25.9-33.1 (29.8±1.4)	25.6-33.7 (29.4±1.7)
Dorsal-fin height	19.5-25.3 (22.2±1.2)	19.7-28.3 (23.5±1.5)
Anal-fin base length	6.7-9.2 (7.8±0.5)	6.4-9.3 (7.8±0.5)
Anal-fin depressed length	17.3-23.6 (20.4±1.3)	18.0-25.0 (21.0±1.3)
Anal-fin height	15.1-21.0 (17.9±1.4)	15.2-23.2 (19.0±1.4)
Pectoral-fin length	21.2-26.7 (23.6±1.4)	19.9-27.6 (24.1±1.4)
Pelvic-fin length	18.1-22.8 (20.4±1.1)	17.8-23.9 (21.1±1.1)
Pre-dorsal length	47.2-53.7 (51.2±1.3)	47.5-57.0 (51.7±1.5)
Post-dorsal length	48.0-59.3 (53.2±2.3)	51.1-60.4 (54.6±2.2)
Pre-pectoral length	24.8-34.5 (28.5±2.1)	23.8-33.2 (29.2±1.8)
Post-pectoral length	71.2-80.2 (74.6±2.0)	62.3-79.9 (74.4±2.3)
Pre-anal length	72.2-83.5 (78.9±2.0)	74.1-84.3 (78.4±1.7)
Post-anal length	20.1-26.2 (23.2±1.2)	19.8-27.4 (24.1±1.3)
Pre-pelvic length	50.6-58.7 (54.4±2.0)	49.3-59.7 (54.4±1.9)
Post-pelvic length	46.5-52.9 (49.7±1.4)	45.6-55.9 (49.8±1.8)
Length from dorsal-fin base to pectoral-fin base	30.4-37.0 (33.3±1.5)	20.7-39.4 (33.0±1.9)
Length from dorsal-fin base to anal-fin base	36.5-44.4 (40.1±1.6)	33.7-43.1 (29.2±1.7)
Length from pelvic-fin base to anal-fin base	23.3-31.4 (26.3±1.5)	22.9-29.5 (25.7±1.2)
Length from pectoral-fin base to pelvic-fin base	24.3-30.0 (27.4±1.2)	22.3-30.4 (26.5±1.3)
Length from pectoral-fin base to anal-fin base	48.8-56.4 (52.9±1.7)	46.3-56.9 (51.4±1.8)
Lower jaw length	4.6-10.5 (7.3±1.2)	4.5-15.7 (7.9±1.6)
Lower jaw width	5.3-9.8 (8.3±1.1)	6.0-12.3 (8.6±1.2)
Upper lip thickness	1.1-2.6 (1.7±0.3)	1.0-2.4 (1.8±0.2)
Lower lip thickness	1.2-2.2 (1.7±0.2)	1.1-1.8 (1.5±0.2)

TABLE 3. Linear correlations with standard length for A) PCA log-transformed morphometric data, B) CVA of log-transformed morphometric data, and C) CVA of CVA of principal components scores excluding PC1. A quadratic equation better fit PC1 with $r^2=0.94822$ and $p<0.0001$.

A)	PC1	PC2	PC3
r^2	0.963922	0.000583	0.00005581
p	<0.0001	0.6837	0.8997
B)	CV1	CV2	CV3
r^2	0.151506	0.000139	0.008466
p	<0.0001	0.8422	0.1199
C)	CV1	CV2	CV3
r^2	0.000282	0.000204	0.000533
p	0.7769	0.8098	0.6969

TABLE 4. Actual vs. predicted classification in the CVA analyses. A) CVA of log-transformed morphometrics. B) CVA of principal components scores excluding PC1.

A)	Predicted Identification			
Actual Identification	<i>N. soroides</i>			<i>N. hendersoni</i>
	normal	lobe	truncate	
<i>N. soroides</i> normal	92	2	6	8
<i>N. soroides</i> lobe	1	13	1	0
<i>N. soroides</i> truncate	5	2	79	4
<i>N. hendersoni</i>	2	1	8	63
B)	<i>N. soroides</i>			
Actual Identification	<i>N. soroides</i>			<i>N. hendersoni</i>
	normal	lobe	truncate	
<i>N. soroides</i> normal	91	3	7	7
<i>N. soroides</i> lobe	1	14	0	0
<i>N. soroides</i> truncate	4	2	81	3
<i>N. hendersoni</i>	2	0	8	64

Although PCA failed to show any distinct differences in morphometry between the morphotypes of *N. soroides*, CVA was successful in classifying specimens into morphotypes as well as in separating *N. hendersoni* (Fig. 2). The morphotypes are sympatric and reportedly consume the same food resources (Khaironizam, 2010). We support Roberts & Khaironizam (2008) that the differences in the lower part of the mouth in *N. soroides* are due to polymorphisms, but given the trends in morphometric differences indicated by CVA and the analysis of Lower Jaw Length vs. Lower Jaw Width, we suggest that the question of the identity of the morphotypes be further examined with genetic techniques.

Zakaria-Ismail (1994) and Lim & Tan (2002) reported that *N. hendersoni* was endemic to Penang. Recently, Ahmad & Lim (2006) reported the occurrence of this species in Langkawi. Both localities are islands at the northwestern part of Peninsular Malaysia. Our specimens from Merbok and Muda drainage in Kedah and Golok drainage in Kelantan appeared to be the first record of the species on the mainland. Until now, the distribution of this species is only known from Peninsular Malaysia and there have been no reports on the occurrence of the species in other localities in Southeast Asia.

Neolissochilus hendersoni in Penang and Langkawi is critically vulnerable because it is limited to certain

areas. This is due to the rapid development in these islands and the occurrence of pollution in the river systems such as several streams in Batu Feringgi, Teluk Bahang and Balik Pulau of Penang (pers. obs.). We believe that further environmental alterations will definitely endanger this species in Peninsular Malaysia.

It is not surprising to find *N. hendersoni* in other localities in the Malay Peninsula, especially in southern Thailand as they can be found in the northern most part of Peninsular Malaysia. Although *N. hutchinsoni* (Fowler, 1938) and *N. paucisquamatus* (Smith, 1945) were described from southern Thailand, they appear similar to *N. hendersoni*. For the time being, we consider those species as valid.

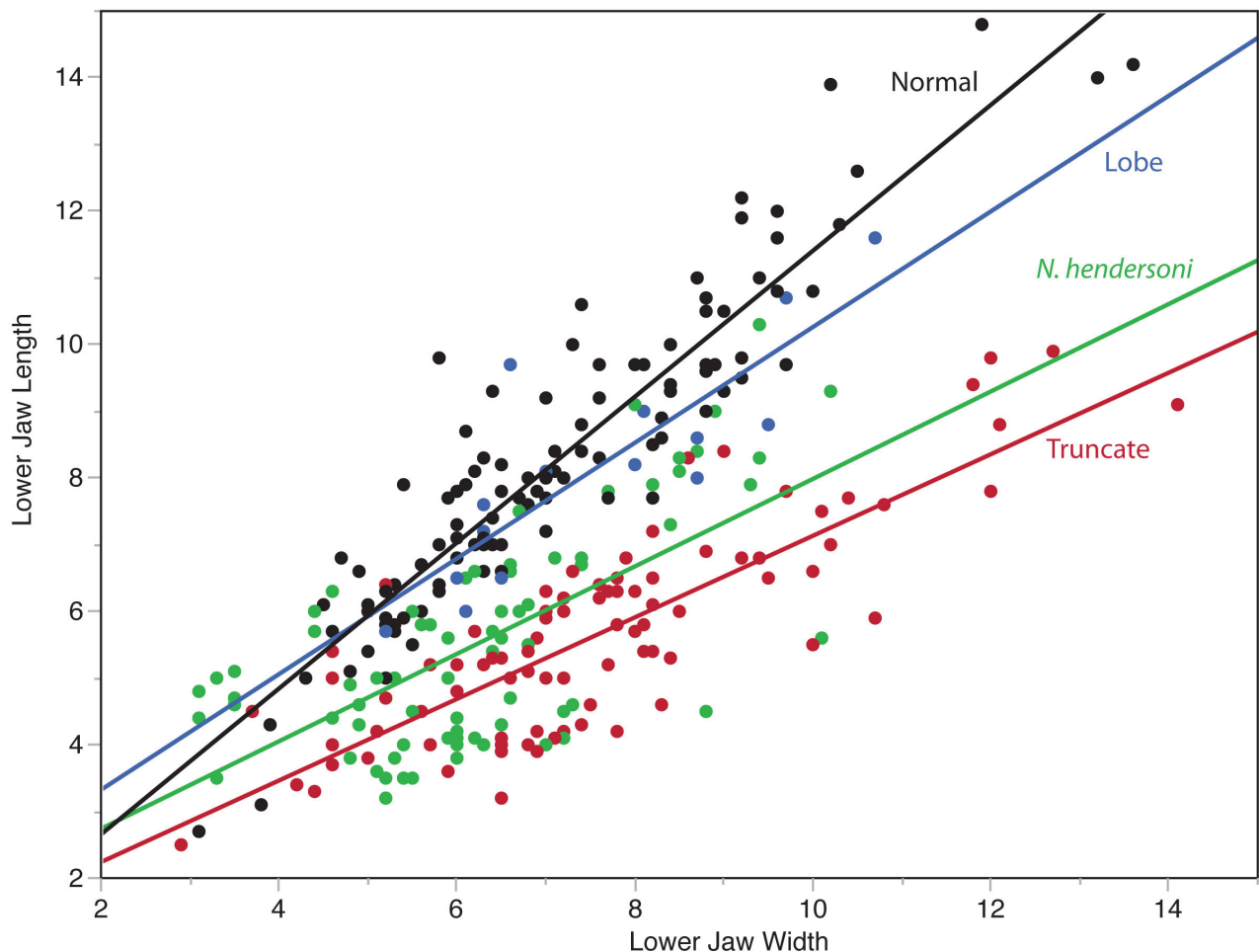


FIGURE 4. Lower Jaw Length vs. Lower Jaw Width. Significant differences were found between all pairs of species/ morphotypes except Normal and Lobe *N. soroides*.

Duncker (1904) indicated that the type locality of *N. soroides* was a stream in the Pahang drainage near Sangka Dua Pass. There is no such place as Sangka Dua Pass in Pahang; however, there is a place called Sangka Dua along the way from Kuala Kubu Baru to Fraser's Hill, and two small streams, Sg. Chiling and Sg. Gamut, pass through Sangka Dua. We believe the type specimens were collected from these streams. Thus the type locality should be Sangka Dua of the Selangor drainage instead of the Pahang drainage.

Herre in Herre & Myers (1937) described *N. tweediei* (as *Lissochilus tweediei*) from the Sg. Yum of the Perak drainage, based on the distinct characters of the lower jaw, which is the truncate morphotype. Roberts & Khaironizam (2008) reported that the flat-edge of the lower jaw and the thickness of the lower lips are only a trophic polymorphism or ecophenotype as observed in other cyprinid fishes. Ismail (1989) compared the meristics and the morphometrics of several specimens of *N. soroides* and *N. tweediei* and also found no significant difference between the two species other than the differences in the lower jaw.

Data from the type specimens of *N. tweediei* and from specimens from the same or nearby the type locality shows no evidence to suggest that *N. tweediei* differs from *N. soroides*. We consider *N. tweediei* to a junior

synonym to *N. soroides*. We agree with Roberts & Khaironizam (2008) that characters of the truncated edge of the lower jaw used by Herre in Herre & Myers (1937) to distinguish *N. tweediei* are the result of trophic polymorphisms.

Ogilvie (1953), Menon (1954), Cramphorn (1983), Mohsin & Ambak (1983), Ambak & Jalal (2006) and Esa *et al.* (2006) reported the occurrence of *N. hexagonolepis* and *N. stracheyi* in Peninsular Malaysia. We have examined specimens from the same localities or the streams near to these localities and found them not to agree with the descriptions of *N. hexagonolepis* and *N. stracheyi*. *Neolissochilus hexagonolepis* has 26–32 scales in the lateral line (M'Clelland 1839; Hora 1940; Jayaram 1981), while *N. stracheyi* has a distinct black lateral stripe running parallel from the end of the operculum to the caudal-fin base (Rainboth 1985, 1996). Therefore, the occurrence of those species in Peninsular Malaysia is doubtful.

Doi (1997) reported the occurrence of *N. dukai*, *N. paucisquamatus* and *N. sumatranus* in the Malay Peninsula. *Neolissochilus dukai* was described by Day (1878) from Darjeeling, India, and we suggest that it be compared with *N. hexagonolepis*, as they seem to share a lot of similarities. *Neolissochilus sumatranus* (Weber & de Beaufort, 1916) seems to be similar to our specimens of *N. soroides*. Roberts & Khaironizam (2008) examined specimens in ZRC and also found them to be similar to *N. soroides* and tentatively concluded that *N. sumatranus* is a junior synonym of *N. soroides*. *Neolissochilus paucisquamatus*, a small fish (45–55 mm length), probably does not occur in Peninsular Malaysia as it was originally reported from northern Thailand and the mountane areas of Nakhon Si Thammarat in Peninsular Thailand (Smith, 1945). This species seems to be similar to *N. hendersoni*.

Ismail (1989) reported the occurrence of *Neolissochilus* sp. with all scales on the body covered with tubercles, a rarity for any Malaysian cyprinid. He recorded it from Sg. Ayer Lanas of the Golok drainage, which is the same drainage in which *N. hendersoni* is found. After close examination of specimens examined by Ismail (UMKL 108), we conclude that they are *N. soroides*. The tubercles are not true tubercles as defined by Roberts (1982), but rather appear to be a manifestation of a fungal infection.

The occurrence of *Tor soro* as reported by Bishop (1973) and Mohsin & Ambak (1983) in Peninsular Malaysia is also questionable. Roberts (1993), in his comments on Bleeker's (1863) description of the Indonesian *Labeobarbus* (*Tor*) *soro*, showed that *T. soro* is similar to *Neolissochilus*, but the holotype of *Labeobarbus soro* has not been located and probably is lost. We examined 61 specimens labeled as *Tor soro* and collected by Bishop in 1969 and 1970 from Sg. Gombak of Selangor (UMKL 5388, 5393, 5403, 5421, 5425, 5426), and the results showed them to be *N. soroides*. We believe that the description of *Tor soro* by Bishop (1973) and Mohsin & Ambak (1983) is based on *N. soroides*.

Taxonomy

Neolissochilus Rainboth 1985

Neolissochilus Rainboth 1985: 26 (type-species: *Barbus stracheyi* Day 1871, by original description; gender: masculine).

Description. Body elongate, relatively deep, broad anteriorly and compressed posteriorly. Trunk slightly arched predorsally, ventral profile straight to convex. Head broad, snout blunt with mouth placement varying from oblique and nearly terminal to horizontal and inferior. Mouth smoothly rounded when lower jaw edge is blunt to nearly truncate when lower jaw edge is sharp; cheek with numerous tubercles, occasionally many anterior to rostral barbel, but never across tip of snout. Lower lip always present medially, with post-labial groove complete or incompletely interrupted. Lips thick, but not hypertrophied. Dorsal fin iv, 9 (rarely iv, 8), with last unbranched ray never serrated on its posterior edge. Pectoral fin i, 13–17, low and pointed, first ray longest and unbranched; pelvic fin i, 8 (rarely i, 7), pointed, first ray longest and unbranched; anal fin iii, 5 pointed with third ray longest and unbranched. Scales large, lateral-line scales 20–29 plus 2–3 on base of caudal fin, circumpeduncular scales always 12. Gill rakers long, slender, each with basal frenulum and medially directed; 2–6 rakers on upper arm and 7–12 rakers on lower arm of anterior side of first arch. Rainboth (1985) provided a detailed description of this genus.

Neolissochilus hendersoni (Herre 1940) (Fig. 5)

Lissochilus hendersoni Herre 1940: 10 (Penang); Tweedie 1940: 73 (Penang); Menon & Yazdani 1963: 113 (Penang); Alfred 1971: 71 (Penang)

Acrossocheilus hendersoni: Alfred 1963a: 146 (Sg. Batu Feringgi, Sg. Teluk Bahang, Sg. Balik Pulau and Sg. Pinang of Penang); Johnson 1967: 724 (Penang)
Neolissochilus hendersoni: Rainboth 1985: 31 (Penang); Ahmad & Lim 2006: 109 (waterfall stream at Durian Perangin, Sg. Korok, Sg. Temah Kecil of Langkawi)

A)



B)



FIGURE 5. A) Lateral view and B) normal mouth type of *Neolissochilus hendersoni* from Sg Air Putih, Pulau Pinang, Peninsular Malaysia (UMKL 3315, 98.4 mm SL).

Material examined. UMKL 6084, 4 ex., 66.5–88.2 mm SL; Peninsular Malaysia: Penang: Ayer Itam: Sg. Air Putih of Pinang drainage; coll. M.Z. Khaironizam, 6 Apr.2006. UMKL 5429, 23 ex., 54.8–120.5 mm SL; Peninsular Malaysia: Kedah: Sg. Batu Pahat of Merbok drainage; coll. A. Shahrudin, 15 Mar.2005. UMKL 6089, 15 ex., 44.6–111.8 mm SL; Peninsular Malaysia: Kedah: Sg. Batu Pahat of Merbok drainage; coll. M.Z. Khaironizam, 9 Jul.2006. UMKL 6090, 1 ex., 102.0 mm SL; Peninsular Malaysia: Kedah: Sg. Tupah of Merbok drainage; coll. M.Z. Khaironizam, 9 Jul.2006. UMKL 6091, 1 ex., 95.1 mm SL; Peninsular Malaysia: Kedah: Sg. Karangan of Muda drainage; coll. M.Z. Khaironizam, 14 Jul.2006. UMKL 6092, 5 ex., 55.6–122.7 mm SL; Peninsular Malaysia: Kedah: Sg. Sedim of Muda drainage; coll. M.Z. Khaironizam, 21 Jul.2006. UMKL 6081, 10 ex., 57.0–74.3 mm SL; Peninsular Malaysia: Kelantan: Sg. Telaga Bijih of Golok drainage; coll. M.Z. Khaironizam, 18 Mar.2006. UMKL 6082, 12 ex., 56.6–76.5 mm SL; Peninsular Malaysia: Kelantan: Sg. Lata Perahu of Golok drainage; coll. M.Z. Khaironizam, 19 Mar.2006. UMKL 6083, 3 ex., 62.4–67.2 mm SL; Peninsular Malaysia: Kelantan: Sg. Sator of Golok drainage; coll. M.Z. Khaironizam, 19 Mar.2006.

Diagnosis. In Peninsular Malaysia, *N. hendersoni* is distinguished from *N. soroides* by the following unique

combination of characters: lateral-line scales 18–22, usually 20 (vs. 20–24, usually 22); transverse scales 3.5/1/2 (vs. 3.5/1/3); predorsal scales 6–8 (vs. 8–10), scales from end of dorsal-fin base to origin of caudal-fin base 10–13, usually 12 (vs. 12–15, usually 14); scales from isthmus to pelvic-fin base 10–12, usually 11 (vs. 12–14, usually 13); scales at anal-fin base 3–5, usually 4 (vs. 4–6, usually 5); total gill rakers 12–14, usually 14 (vs. 14–17, usually, 16); gill rakers on lower arm 9–10, usually 9 (vs. 10–12, usually 11).

Description. General body shape and appearance are shown in Figure 5A. Mouth with smoothly rounded or 'normal' type of lower jaw (Fig. 5B), sub-terminal or inferior. Lower lip present medially, varies, as thick as but never thicker than upper lip, always interrupted by post-labial groove; lips never developed into fleshy lobes. Anal fin when depressed usually reaching origin of caudal-fin base.

Distribution and habitat. Four specimens of *N. hendersoni* were found in runs with rapid flow and crystal clear water in Sg. Air Putih, a stream near Penang Hill Railway Station in Penang. This species was also found in the fast flowing and crystal clear streams of Sg. Batu Pahat and Sg. Tupah, Sg. Karangan and Sg. Sedim, tributaries of the Merbok and Muda drainages in Kedah. Its occurrence in Sg. Telaga Bijih, Sg. Lata Perahu and Sg. Sator of the Golok drainage in Tanah Merah, Kelantan were previously unrecorded (Fig. 1).

Remarks. Scale counts in *N. hendersoni* are lower than those of *N. soroides*, but other characteristics, including body coloration, are similar to those of *N. soroides* as discussed below.

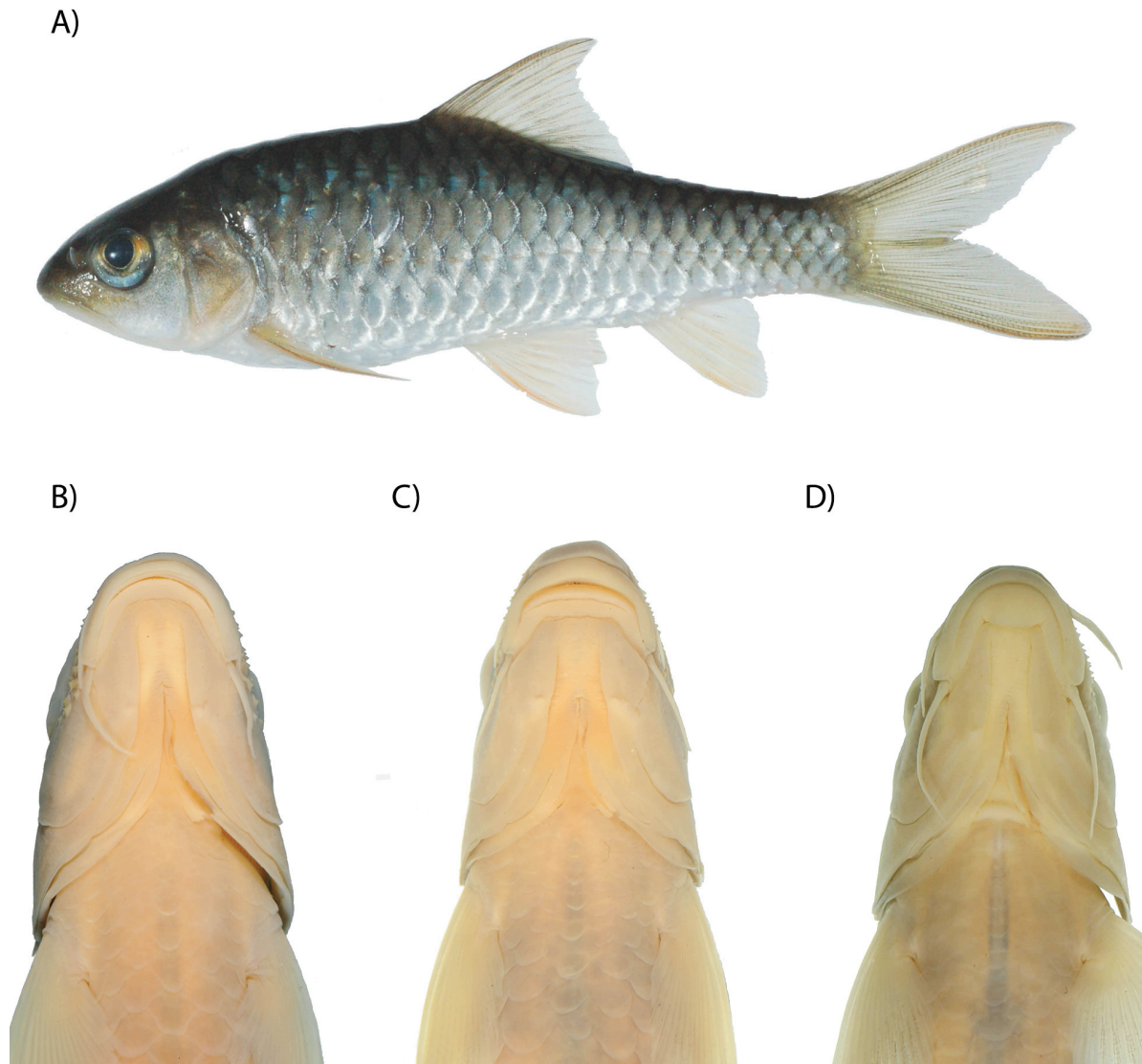


FIGURE 6. A) *Neolissochilus soroides* from Sg. Gombak of Selangor (UMKL 6098, 112.2 mm SL); B) normal mouth type of *N. soroides* from Sg. Chiling of Selangor (UMKL 3315, 98.4 mm SL); C) truncated mouth type of *N. soroides* from Sg. Batang Padang of Perak (UMKL 5411, 58.0 mm SL); D) lobe mouth type of *N. soroides* from Sg. Gombak of Selangor, Peninsular Malaysia (UMKL 6077, 91.8 mm SL).

Neolissochilus soroides (Duncker 1904) (Fig. 6)

- Barbus soroides* Duncker 1904:178 (montane stream at east slope of Sangka Dua Pass, Pahang drainage, Pahang)
- Lissochilus dukai*: Weber & de Beaufort 1916:168 (Peninsular Malaysia); Fowler 1938:66 (montane stream of Pahang drainage, Pahang)
- Lissochilus tweediei* Herre in Herre & Myers 1937:61 (Sg. Yum of the Perak drainage, Perak); Tweedie 1940:73 (stream in Cameron Highland in Pahang and west of Genting Simpah and west of Bukit Telaga in Selangor); Myers 1941:43 (Perak drainage, Perak). *Lissochilus tweediei* Herre in Herre & Myers is herein considered to be synonym of *Neolissochilus soroides* (Duncker)
- Barbus (Lissochilus) hexagonolepis*: Ogilvie 1953:10 (Sg. Tahan of the Pahang drainage, Pahang)
- Acrossocheilus hexagonolepis*: Menon 1954:11 (Kuala Terla, Cameron Highland of Pahang and west of Gunung Simpah of Selangor); Mohsin & Ambak 1983:77 (streams in Langkawi, Cameron Highland, Fraser's Hill and Kota Tinggi); Zakaria-Ismail 1984:24 (Pahang drainage in Taman Negara, Pahang)
- Barbus (Barbodes) soroides*: Ladiges *et al.* 1958:158 (Pahang drainage in Cameron Highland of Pahang)
- Acrossocheilus dukai*: Alfred 1963b:165 (eastern slope of Sangka Dua Pass, Pahang drainage, Pahang)
- Tor soro* Bishop 1973: 350 (Sg. Gombak, Selangor); Mohsin & Ambak 1983:100 (Sg. Bernam, Sg. Kanching and Klang Gate Dam, Selangor); Lim *et al.* 1990: 37 (Sg. Kernam of the Endau drainage in Pahang). *Tor soro* Bishop is herein considered to be synonym of *Neolissochilus soroides* (Duncker)
- Barbus hexagonolepis*: Cramphorn 1983:19 (Sg. Lentang, Sg. Mendak and Sg. Tembat of the Terengganu drainage, Terengganu)
- Neolissochilus soroides*: Rainboth 1985:30 (Pahang drainage, Pahang); Zakaria-Ismail 1993:204 (Sg. Teris and Sg. Rengit of the Pahang drainage, Pahang); Zakaria-Ismail & Lim 1995:321 (Tasik Temengor of the Perak drainage, Perak); Zakaria-Ismail & Fatimah 2005:192 (Sg. Selai of the Endau drainage, Johor)
- Neolissochilus tweediei*: Rainboth 1985:31 (Sg. Yum of the Perak drainage, Perak).
- Acrossocheilus (Neolissochilus) hexagonolepis*: Ambak & Jalal 2006:169 (reservoirs in Peninsular Malaysia)
- Neolissochilus stracheyi*: Ambak & Jalal 2006:169 (reservoirs in Peninsular Malaysia); Esa *et al.* 2006: 23 (Perak drainage, Peninsular Malaysia)

Material examined. UMKL 6097, 15 ex., 71.3–135.5 mm SL; Peninsular Malaysia: Selangor: Sg. Gombak of Klang drainage; coll. M.Z. Khaironizam, 12 Jul.2006. UMKL 6096, 8 ex., 62.0–103.0 mm SL; Peninsular Malaysia: Selangor: Sg. Gombak of Klang drainage, coll. M.Z. Khaironizam, 12 Jul.2006. UMKL 6095, 2 ex., 73.3–115.0 mm SL; Peninsular Malaysia: Selangor: Sg. Gombak of Klang drainage; coll. M.Z. Khaironizam, 12 Jul.2006. UMKL 3327, 2 ex., 73.7–91.8 mm SL; Peninsular Malaysia: Selangor: Sg. Chiling of Selangor drainage; coll. M. Zakaria-Ismail, 7 Nov.1991. UMKL 3314, 6 ex., 60.5–86.3 mm SL; Peninsular Malaysia: Selangor: Sg. Chiling of Selangor drainage; coll. M. Zakaria-Ismail, 7 Nov.1991. UMKL 3315, 3 ex., 76.5–98.4 mm SL; Peninsular Malaysia: Selangor: Sg. Chiling of Selangor drainage; coll. M. Zakaria-Ismail, 7 Nov.1991. UMKL 5923, 1 ex., 131.6 mm SL; Peninsular Malaysia: Negeri Sembilan: Sg. Kenaboi of Pahang drainage; coll. M.Z. Khaironizam, 9 May.2006. UMKL 5933, 1 ex., 76.6 mm SL; Peninsular Malaysia: Negeri Sembilan: Sg. Kemal of Pahang drainage; coll. M.Z. Khaironizam, 10 May.2006. UMKL 5945, 1 ex., 99.4 mm SL; Peninsular Malaysia: Negeri Sembilan: Sg. Kering of Pahang drainage, coll. M.Z. Khaironizam, 18 May.2006. UMKL 5949, 10 ex., 69.3–92.2 mm SL; Peninsular Malaysia: Negeri Sembilan: Sg. Kering of Pahang drainage, coll. M.Z. Khaironizam, 3 Feb.2006. UMKL 5956, 4 ex., 91.7–124.7 mm SL; Peninsular Malaysia: Negeri Sembilan: Sg. Kemal of Pahang drainage; coll. M.Z. Khaironizam, 3 Feb.2006. UMKL 5963, 4 ex., 93.6–119.8 mm SL; Peninsular Malaysia: Negeri Sembilan: Sg. Kemal of Pahang drainage; coll. M.Z. Khaironizam, 3 Feb.2006. UMKL 2791, 13 ex., 67.4–100.6 mm SL; Peninsular Malaysia: Pahang: Sg. Menson of Pahang drainage; coll. M. Zakaria-Ismail, 19 Aug.1990. UMKL 3080, 18 ex., 49.6–86.2 mm SL; Peninsular Malaysia: Pahang: Sg. Kenor of Pahang drainage; coll. M. Zakaria-Ismail, 15 Feb.1993. UMKL 5422, 5 ex., 40.6–132.6 mm SL; Peninsular Malaysia: Pahang: Sg. Juram of Pahang drainage; coll. M. Zakaria-Ismail, 3 Nov.1992. UMKL 4344, 32 ex., 48.7–153.2 mm SL; Peninsular Malaysia: Perak: Sg. Jakal of Perak drainage; coll. M. Zakaria-Ismail, 16 Jun.1993. UMKL 5406, 22 ex., 72.4–128.7 mm SL; Peninsular Malaysia: Perak: Sg. Kerong of Perak drainage; coll. M. Zakaria-Ismail, 16 Feb.1991. UMKL 6087, 19 ex., 63.5–118.1 mm SL; Peninsular Malaysia: Terengganu: Sg. Peres of Terengganu drainage; coll. M.Z. Khaironizam, 2 Jun.2006. UMKL 6086, 15 ex., 63.0–127.4 mm SL; Peninsular Malaysia: Terengganu: Sg. Chemerong of Dungun drainage; coll. M.Z. Khaironizam, 2 Jun.2006. UMKL 6112, 4 ex., 84.7–114.6 mm SL; Peninsular Malaysia: Terengganu: Sg. Cenana of Terengganu drainage; coll. M.Z. Khaironizam, 4 Aug.2007.

Diagnosis. In Peninsular Malaysia, *Neolissochilus soroides* is distinguished from *N. hendersoni* by the

following unique combination of characters: lateral-line scales 20–24, rarely 20 (vs. 18–21, rarely 22); transverse scale 3.5/1/3 (vs. 3.5/1/2); predorsal scales 8–10, usually 9 (vs. 6–8, usually 7), scales from end of dorsal-fin base to origin of caudal-fin base 12–15, usually 14 (vs. 10–13, usually 12); scales from isthmus to pelvic-fin base 12–14, usually 13 (vs. 10–12, usually 11); scales at anal-fin base 4–6, usually 5 (vs. 3–5, usually 4); total gill rakers 14–17, usually 16 (vs. 12–14, usually 14); gill rakers on lower arms 10–12, usually 11 (vs. 9–10, usually 9).

Description. Body elongate, abdomen rounded and peduncle smoothly tapered. Trunk slightly arched predorsally, ventral profile varies from straight to convex. Head relatively broad, snout relatively short and rounded. Eyes moderate in size, located in lateral and upper half position of head and not visible from below ventral surface. Dorsal fin concave, it first simple ray short and embedded into the skin, last simple rays not strongly ossified, never serrated and when depressed, the end tips of last simple rays reaching the end tips of the last unbranched rays. Anal fin truncate, it first and second simple rays short and usually attached to the third and the longest simple rays, when depressed, it not reaching the caudal fin base. Pectoral and pelvic fins pointed and their first simple rays long. Caudal fins deeply forked with convex distal margin of each lobe. Scales large, covering the trunks except on the head, pre occipital areas and areas between the mandibles. Mouth sub-terminal with three morphotypes of lower jaw; first smoothly rounded or blunt edge or normal type (Fig. 6B), second nearly truncate edge or truncate type (Fig. 6C) and third rounded lower jaw edge but with mental lobe or lobe type (Fig. 6D). Lower jaw of normal morphotype always covered by lower lips; lower lips present medially, thickness varies, with or without notches; without fleshy lobes; post labial grooves always interrupted. Lower jaws of truncated morphotype always exposed with trenchant cutting edge covering the horny sheath; lower lips present medially, thickness at the posterior parts always as thick as upper lips and with or without notches, post labial grooves always interrupted; fleshy lobes never occurred. Lower jaw of the lobe type is similar to the normal one but their lower lips developed into fleshy lobes; post labial grooves always uninterrupted.

Coloration. In live specimens, dorsum and upper half of flanks on lateral side varies from light brown to dark greenish-emerald, lateral and operculum coloration light brown to brownish copper, lower half of the flanks and ventrum silvery-white; dorsal-fin base varies from dark greenish-emerald to reddish brown and translucent at tip; caudal-fin base varies from light brown to dark greenish-emerald; pectoral, pelvic and anal fins varies from yellowish-orange to reddish on first simple rays and translucent on other unbranched rays. On preserved specimens, body and fins yellowish brown.

Distribution and habitat. All morphotypes of *Neolissochilus soroides* inhabited the rapid flow and crystal clear waters of the montane streams throughout Peninsular Malaysia (Fig. 1). The normal and the truncated mouth morphs of *N. soroides* are common in the locality most studied, but the lobed type is rare and only recorded from Sg. Gombak (UMKL 3230, 3412, 5418, 6095 and 6098; ZRC 50988 and 50989), Sg. Kerling (UMKL 5117), Sg. Bil (UMKL 4111) of Selangor, Sg. Relong (UMKL 2547) and Sg. Terim (UMKL 2948) of Pahang, Sg. Kenas (UMKL 6093) and Sg. Rui (UMKL 5400 and 5406) of Perak, Sg. Awit (UMKL 6099) of Kelantan and Sg. Peres of Terengganu (UMKL 6085). Recently, this species has adapted itself to reservoirs as well as large rivers flowing into them, such as in Tasik Bukit Merah (UMKL 109) and Tasik Temengor (Zakaria-Ismail & Lim 1995; Ambak & Jalal 2006) in Perak, Selangor dam (UMKL 5154) in Selangor, and Tasik Kenyir (UMKL, 6112, 6113, 6114; Ambak & Jalal 2006) in Terengganu. This species has also been reported in Thailand (Rainboth 1996), Java and Sumatra (Kottelat *et al.* 1993), Anambas Island in South China Sea (Tan & Lim 2004).

Key to species of *Neolissochilus* in Peninsular Malaysia

- 1a. Total gill rakers 14–17; predorsal scales 8–10, usually 9; lateral-line scales 20–24, usually 22; scales on hypural plate usually 3, scales from isthmus to pelvic-fin base 12–14, usually 13. *N. soroides*
- 1b. Total gill rakers 12–14; predorsal scales 6–8, usually 7; lateral-line scales 18–22, usually 20; scales on hypural plate usually 2, scales from isthmus to pelvic-fin base 10–12 usually 11 *N. hendersoni*

Comparative materials

Neolissochilus dukai: CAS-SU 34594 (labeled as *Lissochilus dukai*), 1 ex., 102.0 mm SL; India: Himalayas: Darjeeling; coll. A.W. Herre, 11 Apr.1937. *N. hendersoni*: Holotype—CAS-SU 32632 (labeled as *Lissochilus*

hendersoni), 1 ex., 68.1 mm SL; Peninsular Malaysia: Penang; coll. A.W. Herre; 24 Mar.1937. Paratypes—CAS-SU 68360 (labeled as *Lissochilus hendersoni*), 9 ex., 58.5–62.7 mm SL; same data as holotype. *N. hexagonolepis*: CAS-SU 50201 (labeled as *Acrossocheilus hexagonolepis*), 10 ex., 41.6–115.0 mm SL; Nepal: Chitawan Valley; coll. T.R. Roberts, 29 Apr.1975. *N. soroides*: CAS-SU 68648 (labeled as *Barbus soroides*), 1 ex., 78.4 mm SL; Peninsular Malaysia: Perak: Sg. Batang Padang of Perak drainage; coll. A.W. Herre, 23 Oct.1940. UMKL 5403 (labeled as *Tor soro*), 9 ex., 30.1–64.3 mm SL; Peninsular Malaysia: Selangor: Sg. Gombak of Klang drainage; coll. J.E. Bishop, 27 Mar.1969. UMKL 5425 (labeled as *Tor soro*), 25 ex., 32.2–133.5 mm SL; Peninsular Malaysia: Selangor: Sg. Gombak of Klang drainage; coll. J.E. Bishop, 25 Dec.1969. UMKL 5426 (labeled as *Tor soro*), 1 ex., 45.9 mm SL; Peninsular Malaysia: Selangor: Sg. Gombak of Klang drainage; coll. J.E. Bishop, 25 Dec.1969. UMKL 5421 (labeled as *Tor soro*), 21 ex., 40.6–140.7 mm SL; Peninsular Malaysia: Selangor: Sg. Gombak of Klang drainage; coll. J.E. Bishop, 18 Jan.1970. UMKL 5393 (labeled as *Tor soro*), 2 ex., 64.4–93.5 mm SL; Peninsular Malaysia: Selangor: Sg. Gombak of Klang drainage; coll. J.E. Bishop, 18 Jan.1970. UMKL 5388 (labeled as *Tor soro*), 3 ex., 73.3–99.1 mm SL; Peninsular Malaysia: Selangor: Sg. Gombak of Klang drainage; coll. J.E. Bishop, 18 Jan.1970. ZRC 50996 (labeled as *Neolissochilus soroides soroides*), 3 ex., 75.2–88.8 mm SL; Peninsular Malaysia: Selangor: Sg. Gombak of Klang drainage; coll. M.Z. Khaironizam & T.R. Roberts, 13 Dec.2006. ZRC 50987 (labeled as *Lissochilus*- or *Acrossocheilus* like *Neolissochilus soroides*), 4 ex., 65.2–81.5 mm SL; Peninsular Malaysia: Selangor: Sg. Gombak of Klang drainage; coll. M.Z. Khaironizam & T.R. Roberts, 27 Jul.2006. ZRC 50988 (labeled as extreme *Tor*-like *Neolissochilus soroides*), 1 ex., 104.0 mm SL; Peninsular Malaysia: Selangor: Sg. Gombak of Klang drainage; coll. M.Z. Khaironizam & T.R. Roberts, 17 Jul.2006. ZRC 50989 (labeled as intermediate *Tor*-like *Neolissochilus soroides*), 1 ex., 120.0 mm SL; Peninsular Malaysia: Selangor: Sg. Gombak of Klang drainage; coll. M.Z. Khaironizam & T.R. Roberts, 13 Dec.2006. UMKL 108 (labeled as *Neolissochilus* sp.), 3 ex., 129.9–150.5 mm SL, Peninsular Malaysia: Kelantan: Sg. Ayer Lanas of Golok drainage; coll. M. Zakaria-Ismail, 3 Sep.1985. *N. tweediei*: Holotype of *Lissochilus tweediei*—CAS-SU 30969, 92.9 mm SL; Peninsular Malaysia: Perak: Sg. Yum of Perak drainage; coll. M.W.F. Tweedie, Mar.1933. Paratype—CAS-SU 69113 (labeled as *Lissochilus tweediei*), 2 ex., 63.5–74.5 mm SL; Peninsular Malaysia: Perak: Sg. Yum of Perak drainage; coll. M.W.F. Tweedie, Mar.1933. Paratype—USNM 101191 (labeled as *Lissochilus tweediei*), 1 ex., 67.3 mm SL; Peninsular Malaysia: Perak: Sg. Yum of Perak drainage; coll. M.W.F. Tweedie, Mar.1933. CAS-SU 31166 (labeled as *Lissochilus tweediei*), 1 ex., 68.5 mm SL; Peninsular Malaysia: Perak: Sg. Yum of Perak drainage; coll. M.W.F. Tweedie, Mar.1933. CAS-SU 32641 (labeled as *Lissochilus tweediei*), 4 ex., 46.9–89.4 mm SL; Peninsular Malaysia: 18 miles east of K.L.S. (Probably abbreviation of Kuala Lumpur of Selangor); coll. A.W. Herre, 6 Mar.1937. CAS-SU 68648 (labeled as *Lissochilus tweediei*); 1 ex., 78.4 mm SL; Peninsular Malaysia: Perak: Sg. Batang Padang of Perak drainage; coll. A.W. Herre, 23 Oct.1940.

Acknowledgements

We are grateful to Mohamad Ismail, staff from University of Malaya Field Study Center for their company and field assistance. Special thanks to Amir Shahrudin from Universiti Sains Malaysia for the specimens' loaned, Dr. Tyson R. Roberts for discussion. This study was funded in part by the All Cypriniformes Species Inventory (US National Science Foundation Grant DEB-102340 to JWA). This paper is contribution No. 712 of the Auburn University Museum of Natural History.

References

- Ahl, E. (1933) Ueber eine kleine Fische Sammlung aus dem Toba-See in Sumatra. *Sitzungsberichte der Gesellschaft Naturforschender Freunde, Berlin*, 1932, 514–516.
- Ahmad, A. & Lim, K.K.P. (2006) Inland fishes recorded from the Langkawi Island, Peninsular Malaysia. *Malayan Nature Journal*, 59, 103–120.
- Alfred, E.R. (1963a) Notes on a collection of freshwater fishes from Penang. *Bulletin of the National Museum of Singapore*, 32, 143–154.
- Alfred, E.R. (1963b) Some comments on the type specimens of Malayan fishes described by Georg Duncker. *Bulletin of the National Museum of Singapore*, 32, 165–166.
- Alfred, E.R. (1971) Type specimens of fishes in the National Museum, Singapore. *Journal of the Singapore National Academy*

- Ambak, M.A. & Jalal, K.A.C. (2006) Sustainability issues of reservoir fisheries in Malaysia. *Aquatic Ecosystem Health and Management*, 9, 165–173.
<http://dx.doi.org/10.1080/14634980600701468>
- Bishop, J.E. (1973) *Limnology of a small Malayan River-Sungei Gombak*. Dr. Junk Publisher, The Hague, 485 pp.
<http://dx.doi.org/10.1007/978-94-010-2692-5>
- Bleeker, P. (1863) Systema cyprinoideorum revisum. *Nederlandsch Tijdschrift voor de Dierkunde*, 1, 187–218.
- Boulenger, G.A. (1893) List of the fishes collected by Mr. E.W. Oates in southern Shan State and presented by him to the British Museum. *The Annals and Magazine of Natural History*, 12 (6), 198–203.
<http://dx.doi.org/10.1080/00222939308677602>
- Cramphorn, J. (1983) Sungai Trengganu fish survey, 1980. *Malayan Naturalist*, 3 (4), 16–20.
- Day, F.E. (1869) Remarks on some of fishes in the Calcutta museum: on freshwater fishes of Burma, part 1. *Proceedings of the Zoological Society of London*, 1869, 548–560.
- Day, F.E. (1870) Description of five new species of fishes from Burma. *Proceedings of the Zoological Society of London*, 1870, 99–101.
- Day, F.E. (1871) Monograph of Indian Cyprinidae. *Journal of the Royal Asiatic Society of Bengal*, 40, 277–336.
- Day, F.E. (1873) On some new fishes of India. *Journal of the Linnaean Society of London (Zoology)*, 11, 524–530.
<http://dx.doi.org/10.1111/j.1096-3642.1873.tb01674.x>
- Day, F.E. (1878) *The fishes of India; being natural history of the fishes known to inhabit the sea and freshwaters of India, Burma and Ceylon*. William Dawson & Sons, London, 778 pp.
- Doi, A. (1997) A review of taxonomic studies of cypriniform fishes in Southeast Asia. *Japanese Journal of Ichthyology*, 44, 1–33.
- Duncker, G. (1904) Die fische de Malayischen Halbinsel. *Mitteilungen aus dem Naturhistorischen Museum in Hamburg*, 21, 133–207.
- Esa, Y.B., Kammaruddin, K.R., Khairul, A.A.R., Siraj, S.S. & Tan, S.G. (2006) *Phylogenetic relationship among three freshwater fishes of subtribe Tores (Cyprinidae) in Malaysia*. Proceedings of the International Symposium on the Mahseer, Kuala Lumpur, 23 pp.
- Fowler, H.W. (1934) Zoological results of the third de Schauensee Siamese Expedition, Part I – Fishes. *Proceedings of the Academy of Natural History of Philadelphia*, 86, 67–163.
- Fowler, H.W. (1938) A list of the fishes known from Malaya. *Fisheries Bulletin of Singapore*, 1, 1–268.
- Herre, A.W. (1940) New species of fishes from the Malay Peninsula and Borneo. *Bulletin of the Raffles Museum*, 16, 5–26.
- Herre, A.W. & Myers, G.S. (1937) A contribution to the ichthyology of the Malay Peninsula. *Bulletin of the Raffles Museum*, 13, 5–75.
- Hora, S.L. (1940) The game fishes of India. XI. The mahseers or the large-scaled barbells of India. 4. The bokar of the Assamese and katli of the Nepalese, *Barbus (Lissochilus) hexagonolepis* McClelland. *Journal of the Bombay Natural History Society*, 42, 78–88.
- Hora, S.L. (1941) The game fishes of India. XIII. The mahseers or the large-scaled barbells of India. 6. The jungha of the Assamese, *Barbus (Tor) progeneius* McClelland. *Journal of the Bombay Natural History Society*, 42, 526–532.
- Hora, S.L. & Misra, K.S. (1941) The game fishes of India. XII. The mahseers or the large-scaled barbells of India. 5. The extra-Indian distribution of the bokar of the Assamese and katli of the Nepalese, *Barbus (Lissochilus) hexagonolepis* McClelland. *Journal of the Bombay Natural History Society*, 42, 305–319.
- Hubbs, C.L. & Lagler, K.F. (1964) *Fishes of the Great Lake Region*. The University of Michigan Press, Ann Arbor, Michigan, 213 pp.
- Ismail, M.Z. (1989) *Systematics, zoogeography and conservation of freshwater fishes of Peninsular Malaysia*. PhD Thesis (unpublished), Colorado State University, Fort Collins, Colorado, 473 pp.
- Jayaram, K.C. (1981) *The freshwater fishes of India, Pakistan, Bangladesh, Burma and Sri Lanka: A handbook*. Zoological Survey of India, Calcutta, 475 pp.
- Johnson, D.S. (1967) Distributional patterns of Malayan freshwater fish. *Ecology*, 8, 722–730.
<http://dx.doi.org/10.2307/1933729>
- Khaironizam, M.Z. (2010) *Some biological aspects of Neolissochilus spp. (Teleostei: Cyprinidae) from Peninsular Malaysia*. PhD Thesis (unpublished), University of Malaya, Kuala Lumpur, 215 pp.
- Kottelat, M., Whitten, A.J., Kartikasari, S.N. & Wirjoatmodjo, S. (1993) *Freshwater Fishes of Western Indonesia and Sulawesi*. Periplus Editions, Hong Kong, 221 pp.
- Ladiges, W., von Wahlert, G. & Mohr, E. (1958) Die typen und typoide der fischsammlung des Hamburischen Zoologischen Staatsinstituts und Zoologischen Museums. *Mitteilungen aus dem Hamburgischen Zoologischen Museum und Institut*, 56, 155–167.
- Lim, K.K.P., Ng, P.K.L. & Kottelat, M. (1990) On a collection of freshwater fishes from Endau-Rompin, Pahang-Johor, Peninsular Malaysia. *Raffles Bulletin of Zoology*, 38, 31–54.
- Lim, K.K.P. & Tan, H.H. (2002) Freshwater fish diversity in Peninsular Malaysia: a review of recent findings. In: Ali, A. & Universiti Sains Malaysia (Eds.), *The Asian Wetlands: Bringing Partnerships Into Good Wetland Practices. Proceedings of the Asian Wetland Symposium, 2001*. Penang, Malaysia, pp. 461–481.

- M'Clelland, J. (1839) Indian Cyprinidae. *Asiatic Research*, 19, 217–471.
- M'Clelland, J. (1845) Apodal fishes of Bengal. *Calcutta Journal of Natural History*, 5, 151–226.
- Menon, A.G.K. (1954) Note on the Malayan fishes in the collection of the Raffles Museum, Singapore. *Bulletin of the Raffles Museum*, 25, 5–26.
- Menon, A.G.K. & Yazdani, G.M. (1963) Catalogue of type specimens in the Zoological Survey of India. Part 2. Fishes. *Records of the Zoological Survey of India*, 61, 91–190.
- Mohsin, A.K.M. & Ambak, M.A. (1983) *Freshwater Fishes of Peninsular Malaysia*. Penerbit Universiti Pertanian Malaysia, 284 pp.
- Myers, G.S. (1941) Suppression of *Lissochilus* in favor of *Acrossocheilus* for a genus of Asiatic cyprinid fishes, with notes on its classification. *Copeia*, 1941, 42–44.
<http://dx.doi.org/10.2307/1437708>
- Ogilvie, C. (1953) Some of our rivers and their game fishes. *Journal of Malayan Angling Association*, 1, 9–13.
- Oshima, M. (1919) Contributions to the study of the freshwater fishes of Formosa. *Annals of the Carnegie Museum, Pittsburg*, 12, 169–328.
- Pellegrin, J. & Chevey, P. (1936) Poissons nouveaux ou rares du Tonkin et de l'Annam. *Bulletin de la Société Zoologique de France*, 61, 219–232.
- Pellegrin, J. & Fang, P.W. (1940) Poissons du Laos recueillies par Mm. Delacour, Greenway, Ed. Blanc. Description d'un genre, de cinq espèces et d'une variété. *Bulletin de la Société Zoologique de France*, 65, 111–123.
- Rainboth, W.J. (1985) *Neolissochilus*, a new genus of south Asian cyprinid fishes. *Beaufortia*, 35, 25–35.
- Rainboth, W.J. (1991) Cyprinids of Southeast Asia. In: Winfield, J. & Nelson, J.S. (Eds.), *Cyprinid fishes – Systematics, Biology and Exploitation*. Chapman & Hall, London, pp. 156–210.
http://dx.doi.org/10.1007/978-94-011-3092-9_6
- Rainboth, W.J. (1996) *The taxonomy, systematics and zoogeography of Hypsibarbus, a new genus of large barbs (Pisces, Cyprinidae) from the rivers of Southeastern Asia*. University of California Press, California, 199 pp.
- Roberts, T.R. (1982) Unculi (horny projections arising from single cells), an adaptive feature of the epidermis of Ostariophysan fishes. *Zoologica Scripta*, 11, 55–76.
<http://dx.doi.org/10.1111/j.1463-6409.1982.tb00518.x>
- Roberts, T.R. (1993) The freshwater fishes of Java, as observed by Kuhl and van Hasselt in 1820–23. *Zoologische Verhandelingen*, 285, 1–94.
- Roberts, T.R. & Khaironizam, M.Z. (2008) Trophic polymorphism in the Malaysian fish *Neolissochilus soroides* and other old world barbs (Teleostei, Cyprinidae). *Natural History Bulletin of the Siam Society*, 56, 25–53.
- Smith, H.M. (1945) The freshwater fishes of Siam or Thailand. *Bulletin of the United States Natural Museum*, 188, 1–622.
- Tan, H.H. & Lim, K.K.P. (2004) Inland fishes from Anambas and Natuna Islands, South China Sea, with description of a new species of new species of *Betta* (Teleostei: Osphronemidae). *Raffles Bulletin of Zoology, Supplement* 11, 107–115.
- Tweedie, M.W.F. (1940) Additions to the collection of fishes in the Raffles Museum. *Bulletin of the Raffles Museum*, 16, 68–82.
- Vidthayanon, C. & Kottelat, M. (2003) Three new species of fishes from Tham Phra Daeng and Tham Phra Sai Ngam caves in the northern Thailand. *Ichthyological and Exploration of Freshwaters*, 14, 159–174.
- Weber, M. & de Beaufort, L.F. (1916) *The fishes of the Indo-Australian Archipelago. Vol 3*. E.J. Brill, Leiden, 455 pp.
- Zakaria-Ismail, M. (1984) Checklist of fishes of Taman Negara. *Malayan Naturalist*, 37, 21–26.
- Zakaria-Ismail, M. (1993) The fish fauna of the Sungai Teris and Sungai Rengit, Krau Game Reserve, Pahang, Malaysia. *Malayan Nature Journal*, 46, 201–228.
- Zakaria-Ismail, M. (1994) Zoogeography and biodiversity of freshwater fishes of Southeast Asia. *Hydrobiologia*, 285, 41–48.
<http://dx.doi.org/10.1007/BF00005652>
- Zakaria-Ismail, M. & Fatimah, A. (2002) Fish index for classifying riverine ecosystem of Peninsular Malaysia. *Malaysian Journal of Science*, 21, 1–7.
- Zakaria-Ismail, M. & Fatimah, A. (2005) The fish fauna of the Hulu Selai river system, Endau-Rompin National Park, Johor, Malaysia. In: Mohamed, H. & Zakaria-Ismail, M. (Eds.), *The Forests and Biodiversity of Selai, Endau-Rompin*. Perbadanan Taman Negara, Johor, pp. 191–198.
- Zakaria-Ismail, M. & Lim, K.K.P. (1995) The fish fauna of Tasik Temengor and its tributaries South of Banding, Hulu Perak, Malaysia. *Malayan Nature Journal*, 48, 319–332.
- Zakaria-Ismail, M. & Sabariah, B. (1994) Ecological study of fishes in a small tropical stream (Sungai Kanching, Selangor, Peninsular Malaysia) and its tributaries. *Malaysian Journal of Science*, 15A, 3–7.
- Zittel, K.A. (1881) *Handbuch der Palaeontologie. Abtheilung I, Band II*. Druck und Verlag von R. Oldenbourg, München und Leipzig, 893 pp.